UNCLASSIFIED

| |
|---|
| AD NUMBER |
| **AD838898** |
| NEW LIMITATION CHANGE |
| TO<br>**Approved for public release, distribution unlimited** |
| FROM<br>**Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; AUG 1968. Other requests shall be referred to Rome Air Development Center, Attn: EMATP, Griffiss AFB, NY 13440.** |
| AUTHORITY |
| **RADC, USAF ltr, 17 Sep 1971** |

THIS PAGE IS UNCLASSIFIED

RADC-TR-68-254
Final Report

# A MEGAWATT L-BAND TRAVATRON FOR DIRECT GENERATION OF NANOSECOND PULSES

J. M. Proud
H. J. Huber
W. W. Hirtle

IKOR, Incorporated

TECHNICAL REPORT NO. RADC-TR- 68-254
August 1968



Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York



23

Best
Available
Copy

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related government procurement operation, the government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded, by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacturer, use, or sell any patented invention that may in any way be related thereto.



Do not return this copy. Retain or destroy.

# A MEGAWATT L-BAND TRAVATRON FOR DIRECT GENERATION OF NANOSECOND PULSES

J. M. Proud
H. J. Huber
W. W. Hirtle
IKOR, Incorporated



AFLC, GAFB, N.Y., 23 Aug 68-118

# FOREWORD

This final report was prepared by IKOR, Inc., Burlington, Mass., under Contract F30602-68-C-0119, Project 5573, Task 557306. The project engineer was Ronald C. Blackall, Rome Air Development Center, EMATP, Griffiss Air Force Base, N.Y. 13440.

This technical report has been reviewed and is approved.

Approved: Ronald C Blackall
RONALD C. BLACKALL
Project Engineer

Approved:
WILLIAM T. POPE, JR.
Acting Chief
Surveillance & Control Division

FOR THE COMMANDER
IRVING J. GABELMAN
Chief, Advanced Studies Group

## ABSTRACT

A three megawatt, L-Band Travatron transmitter has been designed and fabricated. The experimental model has been delivered to RADC for extended tests and evaluation. The system produces 1.3 GHz RF pulses having quarter cycle rise time, intrinsic coherency and an absence of time sidelobes. The system and preliminary performance measurements are described in this report.

TABLE OF CONTENTS

# TABLE OF FIGURES

EVALUATION

A MEGAWATT L-BAND TRAVATRON FOR DIRECT GENERATION OF NANOSECOND PULSES

The objective of this effort was to design and fabricate an experimental model of the Travatron and deliver it to RADC for test and evaluation. The Travatron is a nanosecond pulse generator recently invented by IKOR.

Tests at RADC are aimed primarily at determining life expectancy. Plans also include Travatron testing in a radar configuration. This radar test depends on the availability of other components.

No significant conclusions can be drawn from the limited testing performed to date. The Travatron has performed flawlessly in this limited testing but problems have been experienced with periferal equipment, i.e., the charging resistor.

Ronald C Blackall
RONALD C. BLACKALL
Project Engineer

## 1. Introduction

The Travatron is an IKOR invention for the direct generation of radio frequency pulses of short duration and high peak power. This report describes an experimental model of a Travatron transmitter which has been delivered to RADC for extended tests and evaluation. The L-Band system described herein provides the following nominal performance parameters:

| | |
|---|---|
| Pulse Length: | 10 nanoseconds |
| Peak Power: | 3 megawatts |
| PRF: | 150 pulses per sec |
| RF Frequency: | 1.3 gigahertz |

The transmitter system is composed of two portions consisting of a modulator and a Travatron assembly. Emphasis in the four-month program was placed on the latter in order to ensure reliable, stable performance for the RF generation portion of the transmitter. The modulator design employs a simple but proven method for producing a suitable modulator waveform. Performance of the system has been observed in a preliminary manner prior to installation at RADC where more extensive evaluation is in progress. Travatron output has met or exceeded all of the nominal performance requirements and no degradation has been observed.

Section 2 of this report provides a description of the system and the various key components. Preliminary performance data are presented in Section 3. Finally, Section 4 includes an assessment of current Travatron state-of-the-art and recommended future activity.

## 2. The Travatron Transmitter

The Travatron technique for radio frequency generation is aimed at direct generation of short, intrinsically coherent pulses for use as a signal source in high resolution radar. To date, the method has been applied in a frequency range extending from UHF through X-Band with pulse lengths as short as one nanosecond. The technique inherently results in high peak power. For example, the minimum power level of experimental units has been 100 KW, while the multimegawatt level appears readily achievable. Travatron design takes advantage of the short pulse characteristic to obtain unusually small, light weight transmitters for a given peak power level. The L-Band system described in this report was not specifically designed for minimum weight. However, the 3 MW transmitter, including modulator, weighs approximately thirty pounds and is easily transportable.

### 2.1. L-Band System Layout

The delivered L-Band system is arranged according to the block diagram of Figure 1. The modulator portion consists of a resistively charged pulse-forming line which is switched (in this case, on a free-running basis) into the Travatron assembly. The modulator produces a 10 nsec pulse width having a rise time somewhat less than 2 nsec. The pulse height into a matched load is nominally 35 KV. The modulator pulse is carried by means of a short length of RG-17U cable to the Travatron assembly. The cable contains a capacity divider probe $P_1$ which senses the modulator pulse shape.

The Travatron assembly consists of the sealed Travatron tube, its associated termination and an RF coupler. These three pieces are mated by custom connections so that the assembly is an essentially integral unit (see Figure 2). The RF output of the coupler is a standard 1 5/8 in EIA male connector. The Travatron tube contains a permanent RF probe $P_2$ to provide a sample of the RF signal.

The RF load indicated in Figure 1 is not part of the delivered system but is shown in reference to the set up employed during preliminary evaluations and the acceptance test at IKOR. This load consisted of a 1 1/2 in rigid coax line terminated in a calibrated absorber. Probe $P_3$ provided a sample of the output RF signal.

Figure 3 is a photograph of the Travatron assembly. For vertical mounting, as shown, a tripod arrangement is used which is attached directly to the Travatron shell. The components of the assembly may be identified from Figure 2 which also indicates the assembly dimensions.

## 2.2. System Components

The Travatron tube is a permanently sealed tube having the external configuration shown in Figure 2 and 3. The tube consists of a coaxial traveling wave structure and gas envelope which are enclosed within the outer metal shell. The latter also serves as the outer conductor of the device. The input and output connectors are identical, recessed male connectors with modified 1 5/8 EIA flanges. High voltage seals are incorporated in the mating pieces. The probe $P_2$ is permanently installed in the sidewall of the outer shell and includes a standard N-type output fitting.

The RF Coupler, effectively a "tee" with an RF coupled output, is shown in Figure 4. The directional characteristics are such that the modulator pulse is coupled to the Travatron port with negligible loss. Isolation at the RF output for this pulse is approximately 30 db. The insertion loss for the RF coupled path from the Travatron to the output is less than 1 db and RF isolation at the modulator port is approximately 10 db.

Figure 5 is a photograph of the air cooled, Travatron termination. Under nominal operating conditions the termination handles power peaks comparable to the Travatron output power. Average power dissipated is generally less than 10 W.

The modulator switch is shown in Figure 6. This switch, normally pressurized to approximately 100 PSIG, is capable of operation at voltages of 80 KV and pulse repetition rates to 500 pulses per second. RG-17U cables used for the pulse forming line and for interconnecting cable are semi-permanently connected as shown.

## 3. Performance Measurements

Preliminary performance evaluation of the transmitter was conducted at IKOR and included an acceptance test prior to delivery to RADC. Measurements consisted of waveform observation, output power determination and voltage tuning.

### 3.1. Waveforms

Waveforms were generally displayed and recorded by means of a Tektronix 519 traveling wave oscilloscope. All probes (see Figure 1) produced high level signals on the order of $10^2$ volts which were suitably attenuated before display. Precision calibration of probes was not performed, as they were not relied upon for power measurement. Typical transmitter waveforms are shown in Figure 7. Each trace shown is the result of a one-second exposure with the system operating nominally. Thus, in each case, approximately 150 waveform samples have been superimposed. The sweep speed is 5 nsec/lg division for all three waveforms.

The first trace is the modulator waveform as sensed by the capacity divider probe $P_1$. The traveling wave pulse height represented is 36 KV. The rise and fall times are 2 nsec (o to 90% points). The pulse width at half-amplitude is 10 nsec. Approximately 5 nsec following the modulator pulse is a portion (10 db down) of the Travatron produced RF signal which appears in the modulator li

The second tr is derived from $P_2$ showing a sample of the RF signal within the Travatron tube. The second RF burst seen near the end of the trace is due to reflection from the RF load used in power measurement and is not to be confused with a time sidelobe. The latter does not appear in the Travatron as there is no mechanism for time sidelobe generation. The signal from probe $P_2$ is intended primarily as a performance monitor and as a timing or phase reference. It is of interest to note that the output RF peak power from this probe is of the order of 100 W.

Probe $P_3$ is located in the rigid load line at a distance of approximately 2 ft from the Travatron output connector and represents a sample of the full Travatron output. Just prior to the RF signal is seen a small signal corresponding to the slight coupling of the leading edge of the modulator pulse through the RF output port. As in the trace from probe $P_2$ the reflected signal

from the load termination is seen. The proximity to the main signal, of course, owes to the location of the probe relative to the termination. The RF wave train is seen to be reasonably free of amplitude modulation, while it possesses approximately one-quarter cycle rise and fall time.

### 3.2. Power Measurement

Power measurement was performed by measurement of the load termination core temperature rise. In these measurements the pulse repetition rate was maintained at 150 pulses per second for a period of approximately two hours to ensure thermal equilibrium of the resistive load. The peak power was then determined from the average power measurement (nominally 4.5 W) and the duty cycle ($1.5 \times 10^{-6}$).

Calibration of the custom designed termination was accomplished by a DC substitution method in which DC power at several power levels between 2 and 6 W was applied until thermal equilibrium was reached. Typically, equilibrium was attained in thirty minutes. In the power range of interest a temperature rise of 13°F per watt of input power was established as the calibration.

The typical two hour run with the Travatron output replacing the DC source yielded a temperature rise of 60°F above ambient indicating an absorbed power level of 4.6 W. Accounting for the VSWR of the termination, the insertion loss of the RF coupler and the duty cycle, the peak power generated was determined to be 3.3 MW.

### 3.3. Voltage Tuning

The center frequency of the RF signal is dependent upon the modulator pulse height, thus permitting a degree of voltage tuning. Measurement of this dependence was accomplished by noting the average RF period for various modulator pulse heights over a range of approximately ± 20% about the nominal value. Results are shown in Figure 8 in terms of the percentage frequency variation obtainable about the nominal value (1.3 GHz) for percentage variation in pulse height.

## 3.4. Stability

During the preliminary test runs, generally not exceeding two hours of continuous operation, the Travatron has exhibited excellent signal stability. The device, requiring no warm-up period, has been consistently free of long term variation in center frequency or pulse height either during a test run or from day to day. Short term variations, e.g., pulse-to-pulse variations in frequency or pulse height, are attributable to short term modulator pulse height variations. The latter arise from the free-running characteristics of this particular modulator. Long term stability and operating life are currently being evaluated at RADC and, using similar units, at IKOR.

## 4. Conclusions and Recommendations

The L-Band Travatron delivered under this contract typifies the state-of-the-art for megawatt devices in this frequency range. The sealed unit requires no adjustment or maintenance and is operated from a single input delivered from the associated modulator. The Travatron is easily portable and rugged, although minimization of weight or ruggedization were not specifically design goals. The design and fabrication techniques employed are readily applicable to Travatrons operating over a wide frequency range about L-Band.

Preliminary tests and evaluation of the L-Band unit show the Travatron to be a stable, reliable source of high power, nanosecond RF pulses. The intrinsically coherent pulses produced exhibit quarter cycle rise time and an absence of time sidelobes. The peak power and center frequency achieved are close to the design values, while a degree of center frequency tuning is possible.

The present limitations in achieving higher peak power are attributable to the modulator. Techniques, not as yet adapted to the Travatron modulator requirement, are available to permit much higher Travatron power. At L-Band, it is estimated that peak power levels to at least 100 MW can be achieved. With slight modification of the Travatron tube, the present device could be up-graded to 10 MW operation, provided improvement in modulator technique is undertaken. As part of this improvement, the incorporation of accurate modulator timing should be accomplished.

The same modulator techniques which permit extension to higher peak power also lead to much reduced system weight, primarily by reducing weight associated with the DC power source. Preliminary analysis suggests that a 100 MW, L-Band system could be constructed with a total system weight less than 100 pounds.

Preliminary experiments have been conducted to show the feasibility of phase locking arrays of Travatrons. For applications requiring extremely high pulse power, e.g., $10^9$ watts, further development toward Travatron phased arrays should be considered.

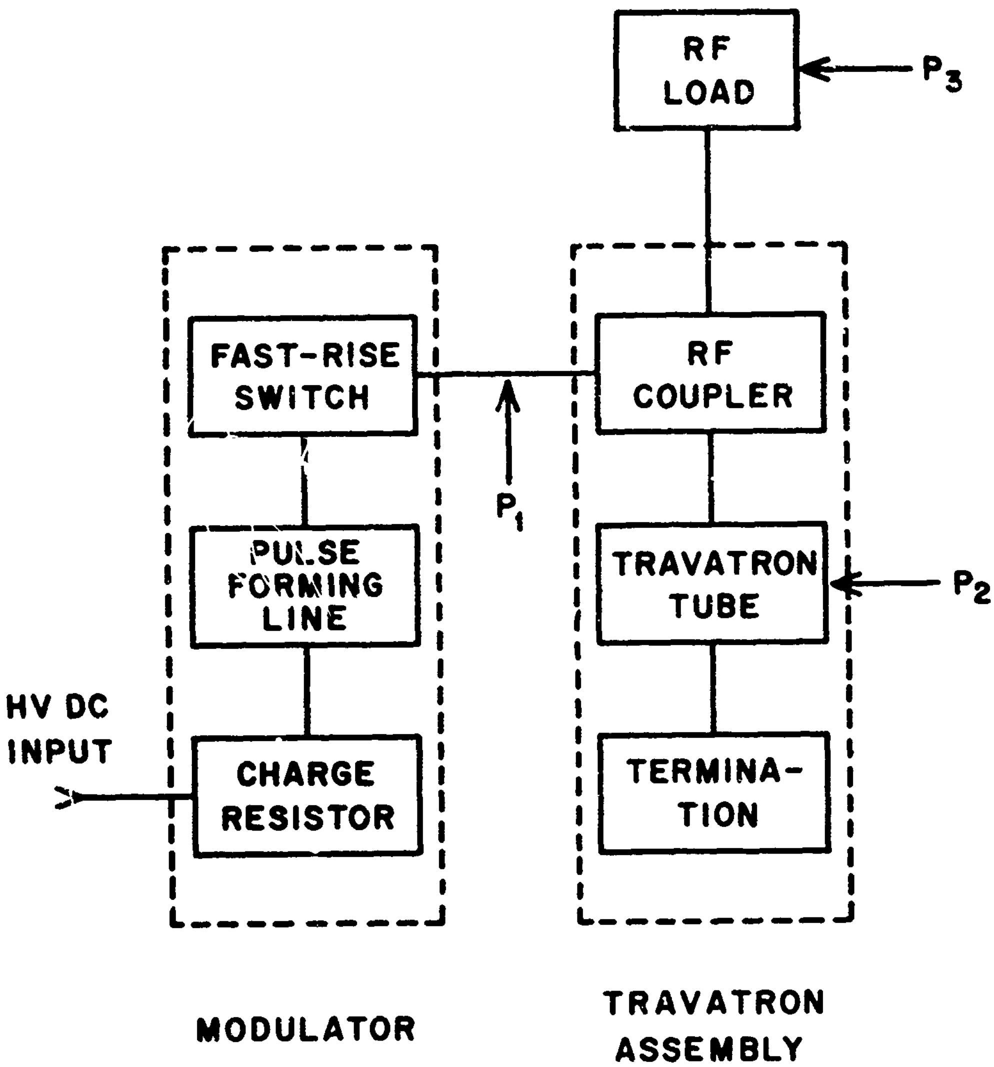



FIGURE 1.

SYSTEM BLOCK DIAGRAM

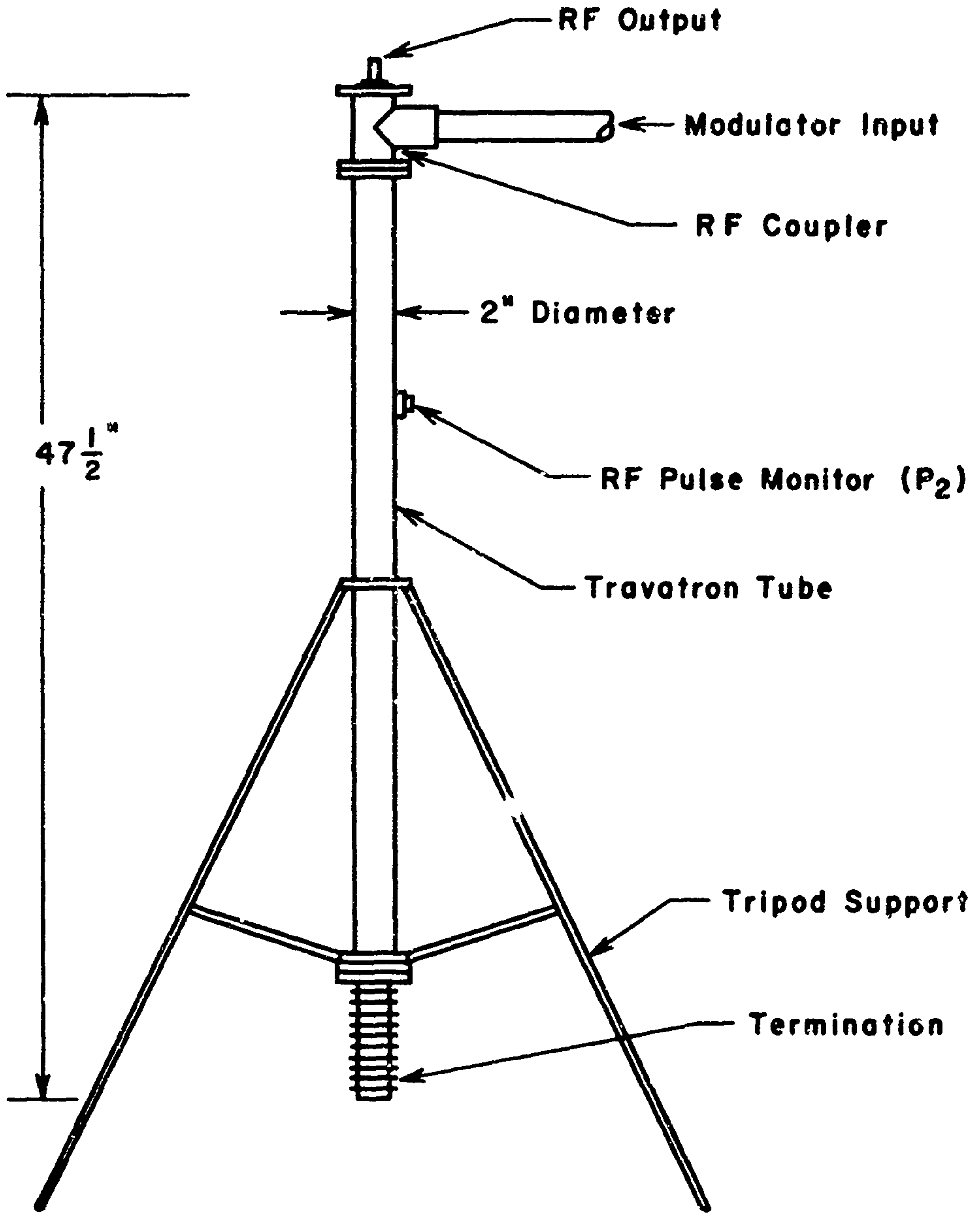



FIGURE 2.

TRAVATRON ASSEMBLY

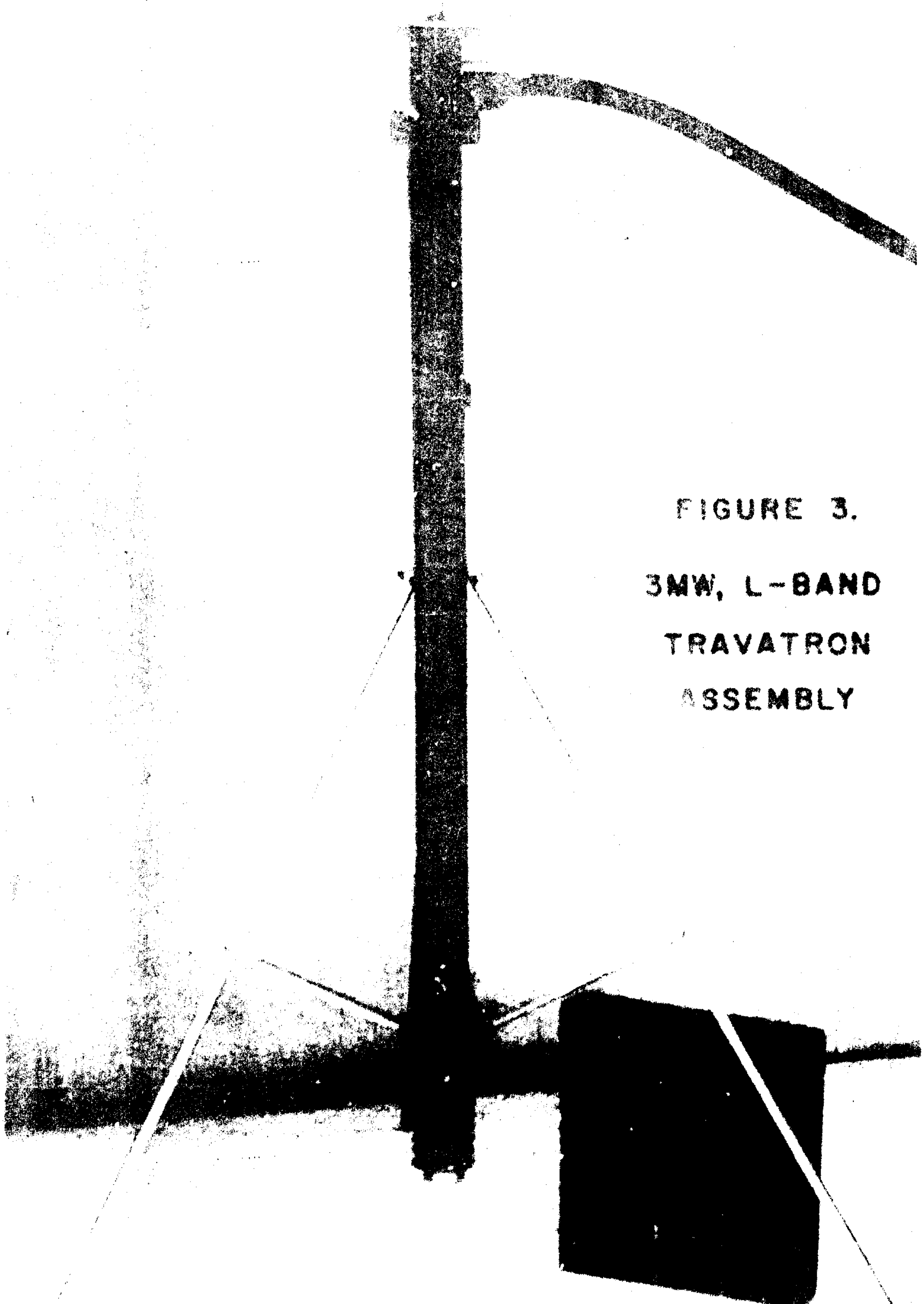


FIGURE 3.

3MW, L-BAND TRAVATRON ASSEMBLY

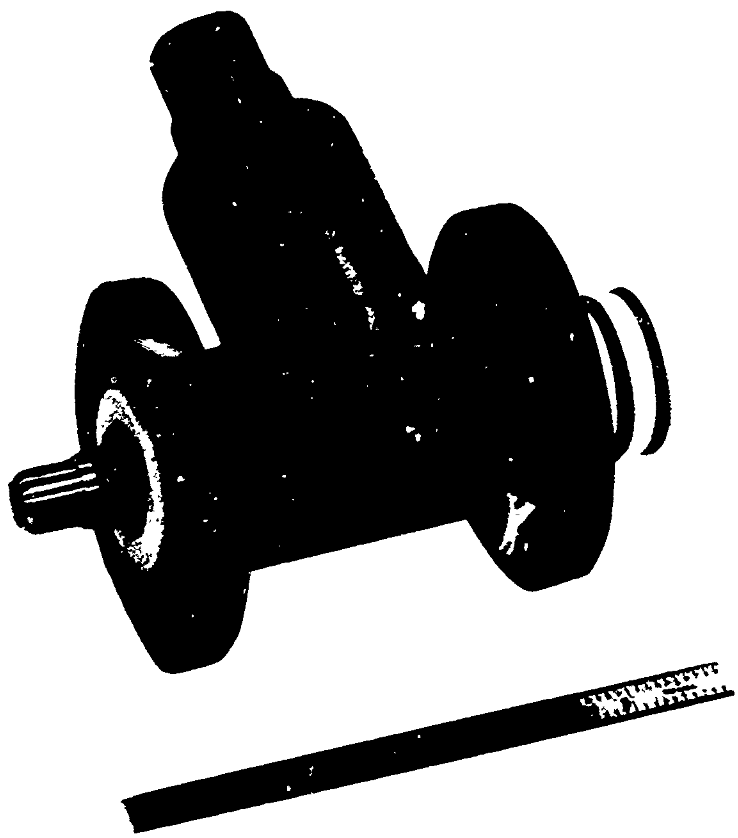


FIGURE 4.

RF COUPLER

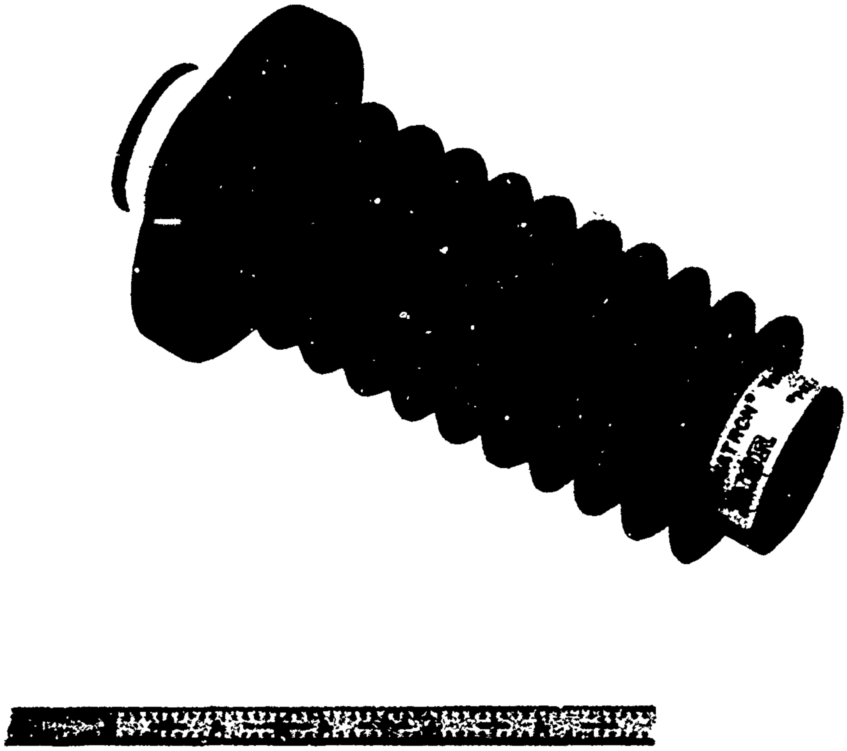


FIGURE 5.

TRAVATRON TERMINATION

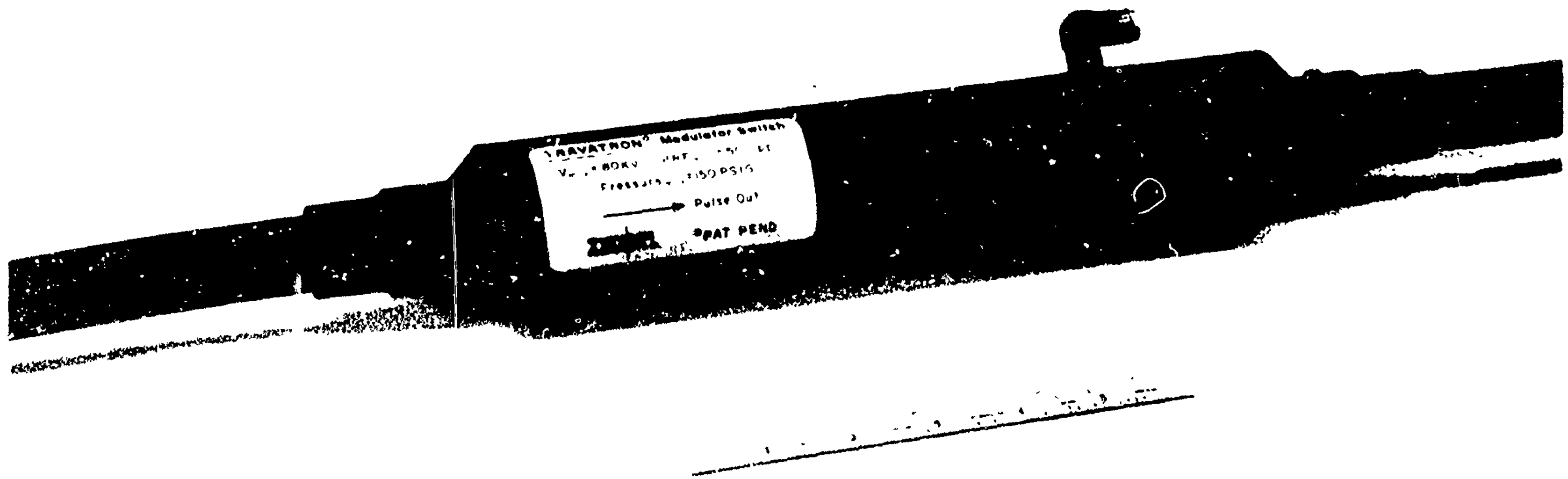
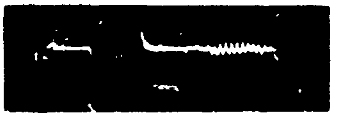



FIGURE 6.

TRAVATRON MODULATOR SWITCH

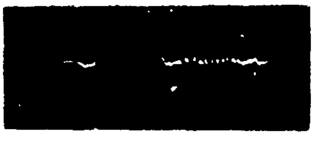
7a

MODULATOR WAVEFORM ($P_1$)



7b

TRAVATRON SIGNAL SAMPLE ($P_2$)



7c

OUTPUT SIGNAL ($P_3$)

Note:
Large Division = 5 nsec

FIGURE 7.

TYPICAL WAVEFORMS

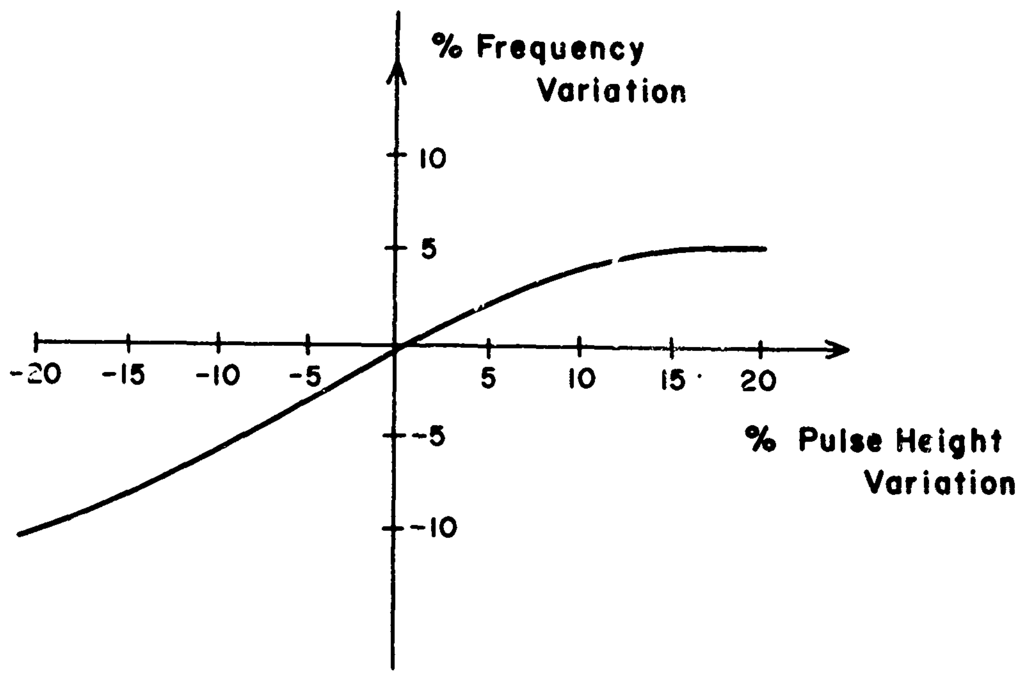



FIGURE 8.

TRAVATRON VOLTAGE TUNING

UNCLASSIFIED

Security Classification

## DOCUMENT CONTROL DATA - R & D

*(Security classification of title body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY (Corporate author)<br>IKOR, Inc.<br>Northwest Ind. Park<br>Burlington, Mass. 01803 | 2a. REPORT SECURITY CLASSIFICATION<br>UNCLASSIFIED<br>2b. GROUP |

3. REPORT TITLE

A Megawatt L-Band Travatron for Direct Generation of Nanosecond Pulses

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final

5. AUTHOR(S) (First name, middle initial, last name)

J. M. Proud
H. J. Huber
W. W. Hirtle

| 6. REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
|---|---|---|
| August 1968 | 25 | |

| | |
|---|---|
| 8a. CONTRACT OR GRANT NO.<br>F30602-68-C-0119<br>b. PROJECT NO.<br>5573<br>c. Task: 06<br>d. | 9a. ORIGINATOR'S REPORT NUMBER(S)<br><br>9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)<br>RADC-TR-68-254 |

10. DISTRIBUTION STATEMENT

This document is subject to special export controls and each transmittal to foreign governments, foreign nationals or representatives thereto may be made only with prior approval of RADC (EMATP), GAFB, N.Y. 13440.

| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY |
|---|---|
| Ronald C. Blackall<br>EMATP<br>AC315 330-4300 | Rome Air Development Center (EMATP)<br>Griffiss AFB, NY 13440 |

13. ABSTRACT


A three megawatt, L-Band Travatron transmitter ~~has been~~ designed and fabricated. The experimental model ~~has been~~ was delivered to RADC for extended tests and evaluation. The system produces 1.3 GHz RF pulses having quarter cycle rise time, Intrinsic coherency and an absence of time sidelobes. The system and preliminary performance measurements are described in this report.


DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED

Security Classification

| 14 KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Hertz Generator | | | | | | |
| Pulse Generator | | | | | | |
| Nanosecond Pulse | | | | | | |

UNCLASSIFIED

Security Classification